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SELF ORGANIZING MACHINES - APPLICATIONS TO UNDERWATER RESCUE AN--ETC(U)
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A DIVISION OF NORTHROP CORPORATION

NORTHROP

SELF ORGANIZING MACHINES -
APPLICATIONS TO UNDERWATER
RESCUE AND RECOVERY

3 November 1964

MOST Project

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SELF ORGANIZING MACHINES - APPLICATIONS TO UNDERWATER RESCUE AND RECOVERY

Informal Presentation

To U.S. Navy Special Projects

By

(10)

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1 Research Park
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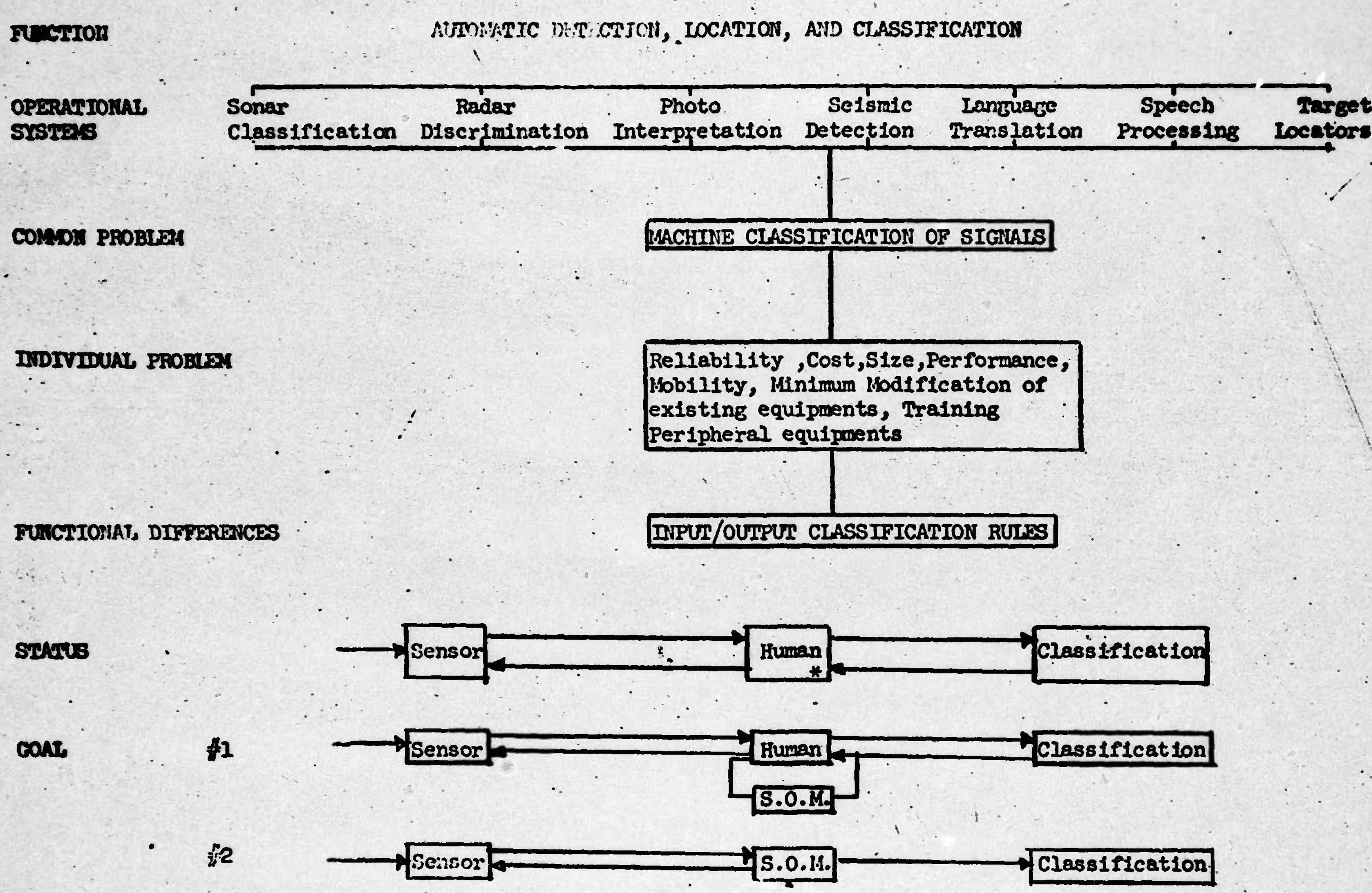

FUNCTION
AUTOMATIC DETECTION, LOCATION, AND CLASSIFICATION
OPERATIONAL SYSTEMS
Sonar Classification
Radar Discrimination
Photo Interpretation
Seismic Detection
Language Translation
Speech Processing
Target Locators
COMMON PROBLEM
MACHINE CLASSIFICATION OF SIGNALS
INDIVIDUAL PROBLEM
Reliability ,Cost,Size,Performance, Mobility, Minimum Modification of existing equipments, Training Peripheral equipments
FUNCTIONAL DIFFERENCES
INPUT/OUTPUT CLASSIFICATION RULES
STATUS
Sensor
Human
*
Classification
GOAL
#1
Sensor
Human
S.O.M.
Classification
#2
Sensor
S.O.M.
Classification

FIGURE 1.

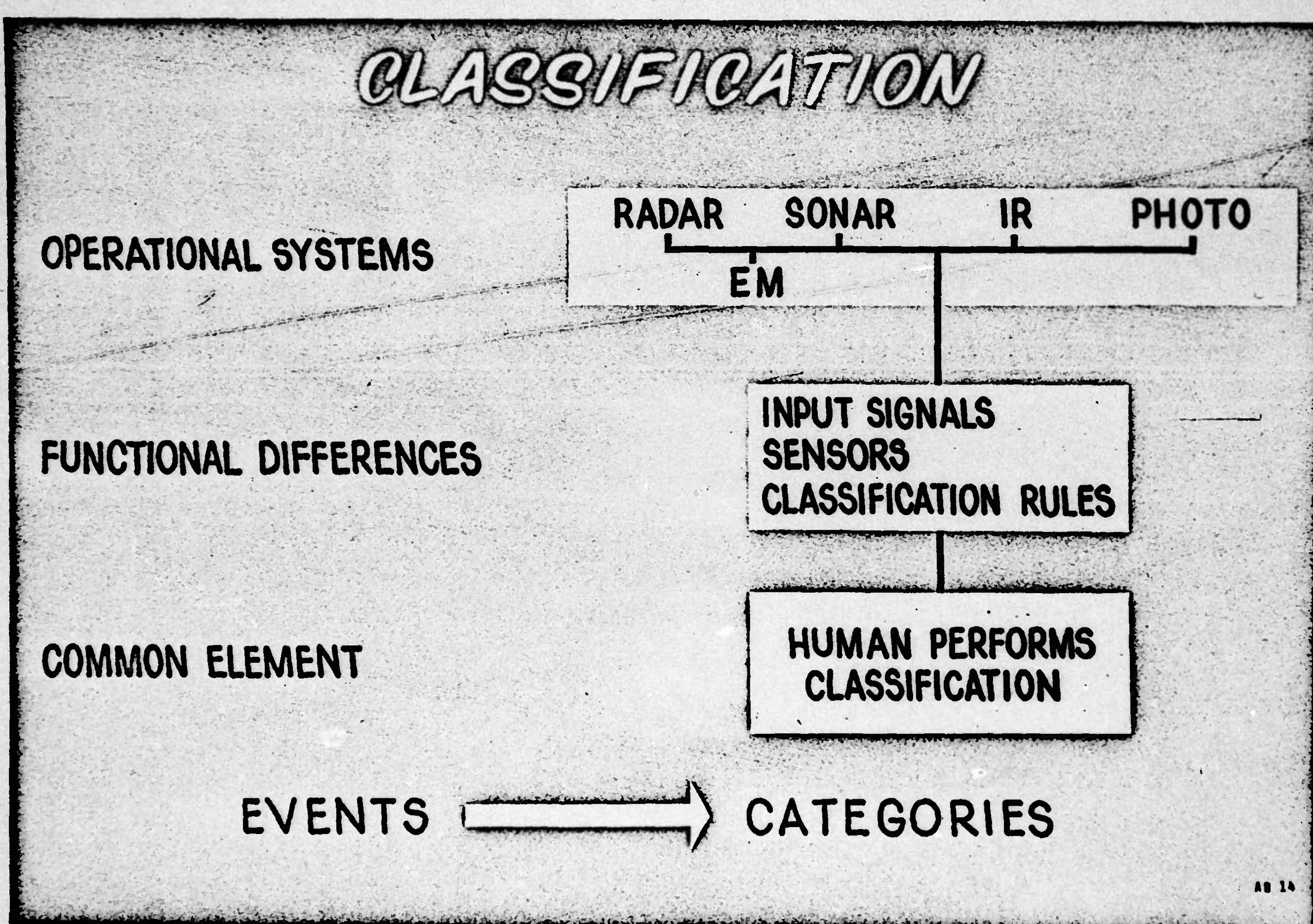
WHAT IS A SELF-ORGANIZING MACHINE

MACHINE ORGANIZES ITSELF INTO A SIMULATION OF AN UNKNOWN TRANSFER FUNCTION AFTER OBSERVING INPUT/OUTPUT HISTORY OF THE PROCESS

FEATURES

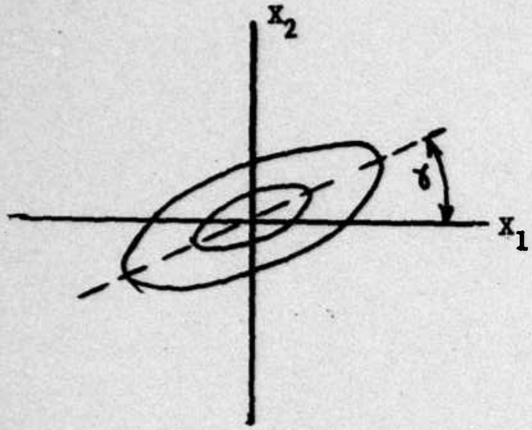
- OPERATES ON OBSERVED RAW DATA
- EXAMINES DETAIL
- ADAPTS TO CHANGE
- STANDARDIZED MECHANISM
- REPORTS SIGNIFICANCE, COMPARES

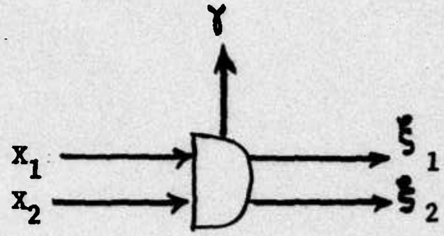
AB 2

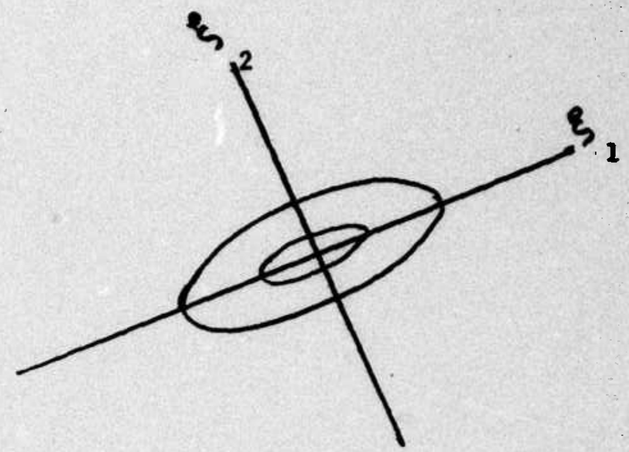


CLASSIFICATION
OPERATIONAL SYSTEMS
RADAR
SONAR
IR
PHOTO
EM
FUNCTIONAL DIFFERENCES
INPUT SIGNALS
SENSORS
CLASSIFICATION RULES
COMMON ELEMENT
HUMAN PERFORMS CLASSIFICATION
EVENTS
CATEGORIES
AB 14

SOMA OPERATION







- CO-ORDINATE TRANSFORMATION
- DECOUPLING OF CORRELATED INPUTS
- DIAGONALIZATION OF A MATRIX
- REDUCTION OF X_1X_2 SIGNAL SPACE TO γ (SCALAR)

RESEARCH GOALS

- DEMONSTRATE THAT A NETWORK OF SELF-ORGANIZING MACHINE ELEMENTS (SOMA'S) CAN PERFORM AN ELEMENTARY CLASSIFICATION TASK
- DEMONSTRATE THAT A GROUP OF SOMA'S CAN PERFORM A SPECIFIC CLASSIFICATION TASK

AB 11

In reply refer to: T4530-64-47

NORTHROP NORTRONICS

inter-office memorandum

to: G. J. Friedman

from: W. F. Hall

subject: SELF-ORGANIZING MACHINES -APPLICATIONS TO DEEP SUBMERGENCE

date: 30 October 1964

copies:

ref:

1. Introduction

For the past several years Nortronics has supported an active internal research program in the area of self-organizing machines. As a part of this program, various applications to automatic pattern recognition have been examined, including machine classification of sonar signals.

The importance of improving classification capability for deterrent/defensive naval forces has been recognized for some time. The development trend of sonar equipment has created a situation where the advantages of improved equipment performance (increased range and sensitivity, for example) has placed a corresponding burden upon the sonar operator's classification ability. Traditionally, the sonar classification task, regardless of the type of equipment; passive, active, processing, or display, always reverts to use of the human brain or a group of brains for final processing and classification. Therefore, substantial improvement in classification capability and speed can be expected where emphasis is placed upon those techniques which relieve the burden of classification on the human operator. However, the solution to this specific problem is one which should be approached from a broader context - that is, the solution of classification problems in general. It is this view which forms the underlying philosophy for Nortronics' research in the field of self-organizing machines.

Stated briefly, the broad objective of our research in self-organizing machines is to:

1. Provide novel and unique techniques which will permit machines to independently acquire the ability to perform a broad spectrum of information processing tasks.

2. Provide techniques which will <u>qualitatively</u> process data as humans do - but without the <u>inherent human quantitative</u> restrictions.

Achieving these objectives will provide for a machine which can accept raw data (for example, sonar audio) and categorize such data as to type and location of targets in a manner essentially duplicating human performance. To illustrate these points and the intrinsic problem more precisely, consider the operational requirements for automatic detection, localization, and classification.

2. The General Problem

The classification task faced by the Navy is not unique, but is one which is common to many operational military systems. The requirement for automatic detection, localization, and classification, though perhaps in different terminology, appears in such systems as:

- Radar Decoy/Target Identification
- Photo Inerpretation
- Target Location
- Sonar Classification
- Speech Processing
- Seismic Detection.

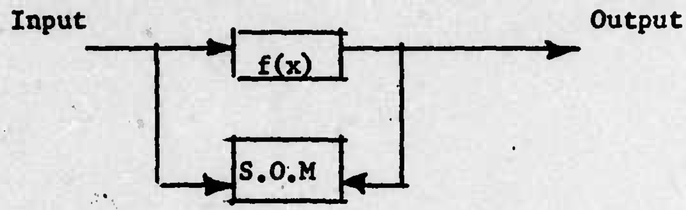
Each of these tasks appears superficially to be a different problem, because the classification rules differ from one task to another and because the input signals and peripheral (sensor) equipments differ -- ranging from mechanical to acoustical to nuclear (see Figure 1). Yet, it is evident that all these tasks have a common element in that each requires associating a set of events with a set of categories. Furthermore, one can observe that the human brain, which may be regarded as a standard mechanism, can acquire the ability to classify; i.e., it can simulate the transformation which maps events onto categories.

As an example of classification and to illustrate a peculiar feature of "category" consider a set of objects which include a screwdriver, hammer, saw, drill, etc. These objects are identified as tools. However, note that one cannot display a tool which is not also either a saw, hammer, screwdriver, or one of the objects that is usually denoted by the category of tools. Thus, one can say that a tool is an abstract concept and that <u>no physical signal can be displayed</u> which means a tool and only tool. That is, a category is only implicitly defined. One may further note that categories may be reported using symbols which again are not categories, but representations of the categories and as such are not intrinsically different from the objects identified as members of the category.

3. Theoretical Developments

The primary direction of Nortronics research into self-organizing systems has been the development of a general description of the functional behavior of self-organization, using the tools of information theory.

The definition: "<u>A machine is said to be self-organizing if, after observing the input and output of an unknown phenomenon (transfer relation), the machine organizes itself into a simulation of the unknown phenomenon</u>," was adopted to specify the behavior required.



For example, suppose f(x) is the transfer relation which describes the relation between the inputs of an automobile (steering, brakes, throttle) and the resultant trajectory (output). Suppose furthermore, that there existed a device which for a given desired trajectory could provide inputs to the automobile such that the automobile realized the desired trajectory. Then an observer would deduce that such a device possessed a simulation of $f^{-1}(x)$. If in addition, said device acquired $f^{-1}(x)$ solely be observing the input-output history which implicitly defines f(x), said device is called a self-organizing machine. Features of such a machine include:

1. It operates on raw data and does not require initial assignment of the significant properties of raw data.

2. It examines detail, but would report only significance.

3. It would classify and compare.

4. It would adapt to changes in the relation it is to simulate.

5. Such a machine would possess a standard mechanism; i.e., one mechanism would be capable of simulating a variety of transfer relations whether they represent classification of radar signals, sonar signals, seismic data, etc.

A summary of the theoretical work on these problems to date was presented in two parts (1,2) at the First Pasadena Invitational Symposium on Self-Organizing Systems, sponsored by the Office of Naval Research in November 1963.

4. The SOMA

A recent outgrowth of Nortronics' research in self-organizing systems is a device which decorrelates correlated random inputs in a suprisingly simple manner. This device, which we call the Self-Organizing Machine Artifact (SOMA), has been mechanized to process audio frequency signals using a circuit built from only a handful of transistors. This makes practical

the construction of many-element SOMA networks whose capabilities we are only now exploring. One obvious application for such a network, the resolution of a complex signal into its independent components, opens interesting avenues of research into pattern recognition, as well as offering possibilities for advances in the more conventional areas of automatic data processing.

Basically, the SOMA is a device which drives the correlation of its two input signals to zero by rotating the original signals through an angle δ to obtain two new linear combinations of the inputs:

$$y_1 = x_1 \cos \delta + x_2 \sin \delta$$

$$y_2 = -x_1 \sin \delta + x_2 \cos \delta$$

After a brief exposure to the input signals x_1 and x_2, the SOMA learns the value of δ which makes y_1 and y_2 uncorrelated. For Gaussian random inputs this rotation makes y_1 and y_2 correspond to the major and minor axes of the ellipses of constant probability density.

5. Immediate Program Goals

A. Demonstration of an Elementary Classification Task (FY 65)

The immediate objective is to demonstrate that a network of self-organizing machine elements can perform an elementary classification task. Because the supply of elements are limited, this initial demonstration will require configuring the task to the machine. Additional technological refinement of the SOMA, theoretical development which provides the synthesis for networks of SOMA's and construction of a network of SOMA's are required to reach this objective.

B. Demonstration of a Specific Classification Task (FY66)

A group of SOMA's will be configured to perform a specific classification task. By specific is meant a task from which extrapolation to an

operationally significant task is relatively straightforward. Furthermore, it is the intent to synthesize a SOMA network to an a priori selected (but no doubt still somewhat primitive) task.

W F Hall

W. F. Hall
Advanced Systems
Orgn. T4531-T30, Ext. 312

WFH:mek

1. NSS Report #2828, "A Topological Foundation for Self-Organization," R. I. Scibor-Marchocki, 14 November 1963.

2. NSS Report #2832, "Conceptual Design of Self-Organizing Machines," P. A. Kleyn, 14 November 1963.